CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

8.1. CONCLUSIONS

The hypothesis that was tested in this study was that the elevated nitrate concentrations detected in the unconfined aquifer are not the result of human activity. The outcomes of the research do not support this hypothesis. While there remain some questions regarding pathways of nitrate to the groundwater, the study showed that the nitrate in the groundwater is the result of human activity. This summary is further detailed below.

8.1.1 Characteristics of nitrate in groundwater

This thesis has presented a review of the historical groundwater data for the Coonawarra area and has shown that nitrate concentrations in groundwater peaked in the early 1980s, and have decreased since this time. Approximately 20% of sampling records are now reporting nitrate concentrations above the drinking water standard of 10 mg/L. This compares with approximately 50% of sampling records collected during the early 1980s.

This reduction in groundwater nitrate concentration is most pronounced in wells in the south, east and central parts of the study area. However in the north-west portion of the study area, in areas dominated by grazing and cropping landuses, wells show increasing trends in nitrate concentrations. Overall there is a decrease in nitrate concentrations in groundwater that is not the result of dilution in the aquifer.

Concerns over water quality have limited the potential for this groundwater to be used as an easily accessible potable supply (although treatment technology is available to reduce nitrate concentrations in potable supplies). Elevated nitrate concentrations continue to pose a risk of health impacts to the community and to the environment (agricultural or natural ecosystems).

Nitrate concentrations are not uniform (or predictably variable) with depth.

Some wells show a gradual decrease in nitrate concentrations with depth, while others do not.

Almost all nitrogen in the aquifer exists as nitrate. Other forms of nitrogen have been detected at times, however these are likely to be the result of direct surface water ingress into the well.

This research has also demonstrated that the nitrate plume previously reported under the study area is unlikely to be continuous. A large proportion of the elevated sampling results are from within the Coonawarra township. The interpretation of these point records as reflective of wider ambient conditions is inappropriate, and has over emphasised the extent of elevated nitrate concentrations in groundwater.

8.1.2 Sources of nitrate to groundwater

The research has applied a number of methods (some for the first time in the South East region of South Australia) to improve understanding of sources and pathways of nitrate to the unconfined aquifer. These methods have included statistical landuse analysis, recharge modelling, nitrate isotope studies and land management-based nitrate leaching modelling.

These analysis have shown that the source of nitrate to the unconfined aquifer is a combination of point and diffuse sources. Nitrate concentrations detected in wells are due to the immediate landuses and surface point sources rather than lateral groundwater transport. In the study area point sources are predominantly subsurface discharge from domestic septic tanks. These point source contributions will locally dominate any diffuse-sourced nitrate in the aquifer.

Nitrate enters the groundwater mostly through vertical infiltration from the surface (or subsurface in the case of septic tank soakage lines). The research has also identified that sub-aquifer entry of nitrate may be occurring at some wells. This is likely to be controlled by preferential horizontal flows in the aquifer, sometimes in combination with layers of low permeability geological units. The study has reported the spatial extent of a confining clay unit that is likely to have resulted in the upper part of the unconfined aquifer (existing within the Bridgewater-Coomandook and the Padthaway Formations) being hydraulically separated from the lower parts of the unconfined aquifer (existing within the Gambier Limestone). This layer is impacting upon the vertical mixing of the aquifer where it exists.

Statistical, recharge and land management leaching modelling has shown that while the centre of the study area is dominated by vineyard development, and vertical diffuse recharge is high in this area, this landuse is not a significant source of nitrate entering the aquifer. Modelling indicates that irrigation practices employed in some vineyards (frost and summer-growth irrigation) will considerably increase the drainage of water to the aquifer, however this does not result in substantial leaching of nitrate to the groundwater. This is primarily because of low inorganic nitrogen content within the soil profile.

Diffuse inputs of nitrate to the aquifer have been modelled and results show that under natural vegetation landcover they are low. This suggests that under steady state natural vegetation, there will be negligible nitrate leaching to the unconfined aquifer, and an increase in the soil organic nitrogen pool. The modelling of other agricultural land management regimes illustrates that where there is no regular input of nitrogen to the environment (to replace gaseous losses, leaching losses and plant removal), there is a reduction in soil organic nitrogen. In all of the land management systems modelled in this study, the soil organic nitrogen pool dominated the soil inorganic pool.

Modelled pasture grazing and legume cropping landuses produce the highest nitrogen concentration in drainage water (approximately 4 – 6 mg/L) as well as the highest inter-annual variability of leached nitrate. The modelled nitrogen concentrations in drainage water are lower than some other studies, but are consistent with the groundwater data collected from the study area.

This appears to be the first time that nitrogen and oxygen isotopes have been applied to nitrate source determination studies in groundwater in Australia. This method confirmed that the nitrate in groundwater displayed isotopic characteristics that were consistent with nitrate from either mineralisation of soil organic matter, or from septic waste.

8.1.3 Relevance to Future Research

The findings of this study are relevant to others being undertaken in similar physical environments both within and beyond South Australia.

This thesis provides a comprehensive review of historic water quality data for the study area that is more widely applicable. Separate approaches are presented to allow standardised reporting of temporal concentration nitrate trends in groundwater. These methods provide increased rigour to improve confidence in temporal trends, while recognising the influence of point and diffuse sources of nitrate.

Considerable resources were required to collate the historical data, and it is likely that the expenditure of effort will not be practical for studies that cover a greater spatial extent. The research has demonstrated that there are significant quality control issues with current data storages, and provides guidance on how these can be addressed. However it is likely that the 'cleaning' of water quality data will only occur during similar research programs. There are however procedures that can be adopted to reduce the risks of these quality control issues occurring in the future, and to limit the inappropriate reporting of the data already compromised.

The research has shown that at the study area scale, point sources and diffuse sources are difficult to distinguish based upon nitrate concentrations and land mapping techniques alone. There is a risk of assuming sources and pathways are consistent across the landscape. Given the location of many of the bore sites, it is suggested that the higher concentrations are reflective of localised sources (point sources) and not necessarily diffuse sources.

Because of the kriging process adopted by Schmidt and his colleagues (1998), the relatively small number of very high nitrate concentrations within the township of Coonawarra would have influenced final classification of the surrounding area. Contour mapping of groundwater nitrate concentrations can produce the same unrealistic visualisation (Dillon 1988) and therefore has been avoided in this research.

Statistical analysis aimed at determining the relationship between mappable land features and groundwater nitrate concentrations is unlikely to produce results that are useful for resource planning where there is a combination of diffuse and point sources. This study was able to explain 39% of the nitrate variability based upon land feature classification. The reasons for this unexplainable variability in nitrate concentrations are considered to be significant local variability in land management, recharge rates and soil structures as well as compounding effects of localised point sources. For aquifers such as that investigated in this study, the use of statistical methods in this way is not recommended.

Tritium modelling has reported recharge rates throughout the study area that appear to be generally low in comparison to other studies. Higher recharge rates are reported in the centre of the study area and these correspond to higher nitrate concentrations. The opportunities to use tritium as a isotopic tracer are now limited. However the outcomes of the study suggest that with greater care in sampling from the surface of the unconfined aquifer, the use of contemporary tracers (e.g. $^{3}H/^{3}He$) could further quantify diffuse groundwater recharge to unconfined aquifer in the South East region.

The nitrogen-oxygen isotopic method has provided useful information for source determination of nitrate in groundwater. While the analytical costs of this method are moderately high (approximately $150 a sample), the method can provide reliable results. Coupled with careful site selection (to recognise potential local point sources), this method presents a feasible option for investigating nitrate sources to groundwater. This method however should not be applied on its own. An understanding of the landscape (anthropogenic and natural components) and hydrogeology will be necessary to allow contextual interpretation of the results.

The use of a one-dimensional leaching model was also found to provide useful information for the interpretation of the nitrogen-oxygen isotopic assessment. The LEACHN model allows a desk-top assessment that can be cost-effective and relatively quick. The modelling approach does not require intensive field assessment, and has been shown here to provide realistic results when using literature-based information.

8.1.4 Relevance for Aquifer Management

Diffuse sources are likely to be a major pathway for nitrate contamination of the aquifer in the region. Sources of nitrate previously reported as resulting in a large plume centred on the Coonawarra township are most likely to be located close to the wells. Primarily the sources are domestic septic tanks, although past effluent discharges by winery operators may also have impacted upon local nitrate concentrations. Although these sources (i.e. septic tanks and possibly wastewater discharge) may have now raised the ambient concentrations of nitrate in groundwater in this vicinity, there remains considerable variability of nitrate within this small area.

This study suggests domestic point source discharges may be a significant cause of groundwater degradation in the South East region, and that they may be having considerable local impacts. A variety of technologies exist to reduce nitrogen leaching from domestic wastewater disposal, and this may need to receive further attention in the region.

Variability in land management practices is expected to be the primary factor leading to variability of nitrate leaching and subsequent contamination of underground aquifers in the region. However, the monitoring and modelling of these land management practices is problematic (and potentially costly).

Further research will need to balance the issues of scale (whether intensively assessing smaller areas, or broadly considering a range of land systems).

Mineralisation of soil organic matter may present a significant diffuse source of nitrate leaching. The size of the organic nitrogen pool within soils (even those soils not considered organically-rich) is high compared to nitrogen fluxes. The organic nitrogen pool in the shallow soils in the study area is estimated to more than 18,000 kg/ha. Any processes that accelerate the mineralisation of this organic pool may increase nitrate leaching to the groundwater (e.g. cultivation, irrigation). Modelling has suggested that leaching of nitrate to the aquifer may be occurring in appreciable levels even where there is no significant application of nitrogen to the system.

8.2. RECOMMENDATIONS

Based upon the research undertaken, the following recommendations are made:

Recommendation 1: All groundwater sampling undertaken by state government authorities, as part of ambient monitoring programs or specific projects should be reviewed to ensure that the methodologies are in accordance with acceptable monitoring standards, and that adequate documentation is maintained.

Recommendation 2: All SAGEODATA water quality data prior to 1980s should be reviewed and a determination made as to whether the data availability is restricted given the apparent errors in nitrogen concentration units.

Recommendation 3: Random groundwater sampling should be avoided, and a commitment made to longer-term monitoring of bores that are appropriately constructed and located to take into account the monitoring purpose of the bores.

Recommendation 4: Bores that are presently identified as having inappropriate protection should be upgraded, excluded from monitoring programs, or replacement monitoring bores constructed nearby, with the bores backfilled.

Recommendation 5: Effort not be directed towards statistical methods of comparing landuse regimes to nitrate concentration in the South East region.

Recommendation 6: The nitrogen-oxygen isotopic method for nitrate source determination be incorporated as a integral part of groundwater assessment of elevated nitrate concentrations.

Recommendation 7: Further research be undertaken to assess the benefits and costs of incorporating improved standards for onsite domestic wastewater disposal systems to limit the discharge of nitrate directly to the aquifer.

Recommendation 8: Consideration be given to ensuring that landowners are aware of the potential health impacts associated with extracting groundwater that may have been impacted by septic tank disposal (pathogens as well as nitrates).